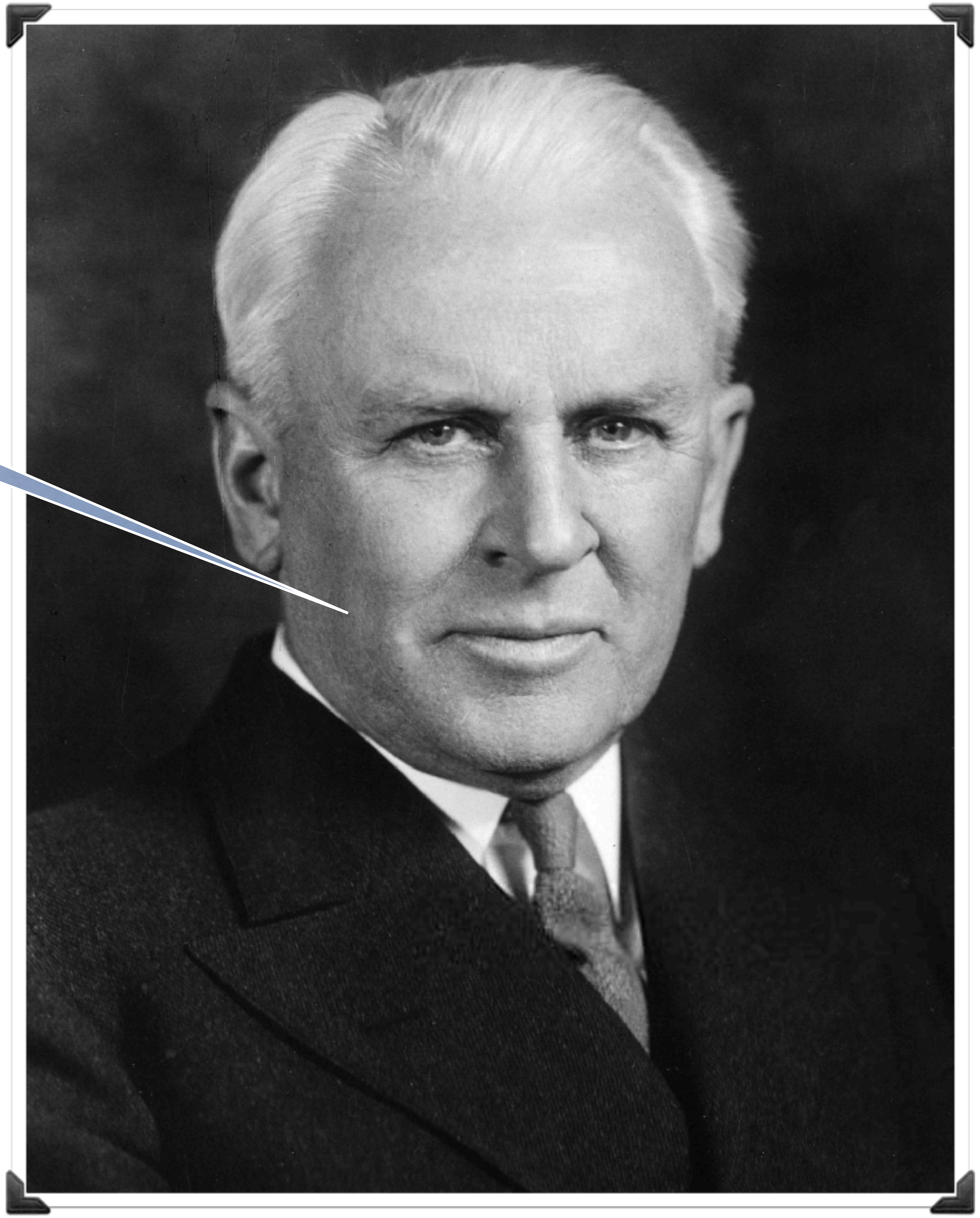
Welcome Back to
Physics 1308

Electric Potential



Robert Millikan
1868 - 1953

Announcements

- **Assignments for Thursday, September 13th:**
  - Reading: Chapter 24.7
  - Watch Video: https://youtu.be/M0ahG-A0Nko — Lecture 7 - The Energy of Assembly
- **Homework 4 Assigned - due before class on Tuesday, September 18th.**
- **Midterm Exam 1 will be in class on Thursday, September 20th.**


KEEP
CALM
AND
ITS
QUIZ TIME

Review Question 1

When a particle with a charge Q is surrounded by a spherical Gaussian surface, the electric flux through the surface is Φ_S. Consider what would happen if the particle was surrounded by a cylindrical Gaussian surface or a Gaussian cube. How would the fluxes through the cylindrical Φ_{Cyl} and cubic Φ_{Cubic} surfaces compare to Φ_S?

a) $\Phi_S = \Phi_{Cubic} > \Phi_{Cyl}$

b) $\Phi_S > \Phi_{Cyl} = \Phi_{Cubic}$

c) $\Phi_S = \Phi_{Cyl} = \Phi_{Cubic}$

d) $\Phi_S < \Phi_{Cubic} < \Phi_{Cyl}$

e) $\Phi_S > \Phi_{Cubic} > \Phi_{Cyl}$

Key Concepts

Change in Electric Potential

If the particle moves through a potential difference ΔV, the change in the electric potential energy is

$$\Delta U = q\,\Delta V = q(V_f - V_i).$$

Work by the Field

The work W done by the electric force as the particle moves from i to f:

$$W = -\Delta U = -q\,\Delta V = -q(V_f - V_i).$$

Conservation of Energy

From the conservation of energy we can derive an expression for the change in kinetic energy:

$$\Delta K = -q\,\Delta V = -q(V_f - V_i).$$

Work by an Applied Force

If some force in addition to the electric force acts on the particle, we account for that work

$$\Delta K = -\Delta U + W_{app} = -q\,\Delta V + W_{app}.$$

- Work done by a conservative force field is W (e.g. electric field); work done by an external applied force in the presence of that field is W_{app} = -W. Work done on a charge is related to changes in kinetic energy, K, by W = ΔK.

- Work done by the field is related to changes in potential energy: W = - ΔU

- Work done by a uniform electric force, working to displace a charge by a distance, Δr, is related via $W = \vec{F} \cdot \vec{r}$

- The change in electric potential between two points, i and f, exists whether or not there is a charge there and is related to changes in potential energy between the two points by: $\Delta V = V_f - V_i = \Delta U/q$

- Like all conservative force fields (think GRAVITY), the electric field wants to move charges from regions of HIGH potential energy to regions of LOW potential energy.

  - For positive charges, this means moving further ALONG the arrows of electric field lines

  - For negative charges, this means moving further AGAINST the arrows of electric field lines.

- Just as in gravity, you have freedom to define where ZERO potential energy (or electric potential) are located. In a problem involving electric potential or electric potential energy, it's wise to set the zero point at the place where the field wants to move charge → this usually simplifies the problem.

Question 1

Why is an electrostatic force considered a conservative force?

A) Charged particles do not experience friction, which is a non-conservative force.

B) The energy required to move a charged particle around a closed path is equal to zero joules.

C) The work required to move a charged particle from one point to another does not depend upon the path taken.

D) Answers (a) and (b) are both correct.

E) Answers (b) and (c) are both correct.

Instructor Problem: 9V Battery on Tongue

You decide to test an old 9.0V battery to see if it's any good. One way to do this (quickly and cheaply) is to touch your tongue to the battery terminals.

When you do this, -0.18C of charge is driven through your tongue in 1.0s. What is the kinetic energy gained by the electrons during this process? What power is delivered to your tongue?

(By the way, this hurts – try it at home with extreme caution!)

First draw a diagram and take account of what we are given.

-0.18 C

Given: $\Delta V = 9\ V$

$|q| = 0.19\ C$

$\Delta t = 1.0\ s$

Find: Power

$$P = \frac{\Delta KE}{\Delta t}$$

We also know that energy is conserved and that energy gained by transversing this potential difference goes into potential energy. So,

$$W_{field} = \Delta KE$$

The electric field in the battery results in a ΔV that gives rise to a ΔU that gives rise to W_{field} and thus, ΔKE. So, we can relate ΔKE to ΔV:

$$\Delta KE = W_{field} = -\Delta U = -(U_f - U_i)$$

Aside: Note that the field drive the electrons from *high* to *low* potential energy. So, we could let $U_f = 0$. Then …

$$\Delta KE = -(-U_i) = U_i$$

We know that

$$\Delta V = \frac{\Delta U}{q} \quad \longrightarrow \Delta U = q\Delta V$$

We can relate ΔKE to ΔV:

$$\Delta KE = -\Delta U \quad = -q\Delta V$$

Power is

$$P = \frac{\Delta KE}{\Delta t} = \frac{-q\Delta V}{\Delta t} = \frac{-(-0.18\ C)(9.0\ V)}{(1.0\ S)} = 1.6\ W$$

$$\boxed{P = 1.6\ W}$$

If all of this energy is dumped into your tongue each second, it can warm 1 g of water in your salty tongue by 1 degree C every 3-4 second!

Student Problem: The Electric Eel

HINT: 1 food calorie is known formally as a "Calorie" (capital C), and is actually equal to 1000 calories (little c), where 1c = 4.186J. 1c is the energy required to raise 1g of water 1ºC in temperature.

Electric Eels possess a series of large organs that are capable of generating a 600V electric potential difference. Using this, they can drive an electric current of 1 Ampere (1C/s) through prey, stunning or killing in the process.

If an electric eel wants to stun a large fish and needs to generate this current for 2 seconds, how many food calories must an eel have consumed to sustain such a burst of electric energy?

First step is to take account of what we know.

Given:

$$\Delta V = 600\ V$$
$$I = 1\ C/s \rightarrow (current)$$
$$\Delta t = 2\ s$$

Since the problem is about energy, we assume conservation of energy and we assume that food calories are converted to energy that can be used by the eel's body to generate the electric potential difference. Thus, the original source of energy, U, will be converted to the electric potential difference we are given. Hence, we need to relate that energy, U, to the electric potential difference.

$$U = qV$$

Next we need to find q.

$$q = I\Delta t$$

Now we can substitute into expression for U

$$U = (I\Delta t)V \quad = (1\ C/s \times 2\ s)(600\ V)$$
$$= 1200J$$

recall V = J/C

Since each calorie is 4.186 J, the amount of calories "c" is

$$\mathrm{U} = 1200\ \ \mathrm{J} = 287\ \mathrm{c}$$

One food calorie is 1000 calories (1000 c) so this is 0.29 C of energy.

Student Problem: Portable Defibrillator

A portable defibrillator can store a large charge. The charge can be released across the heart to restart it.

The device can move -145 μC of electrons through an electric potential difference of $\Delta V = 2.3\text{kV}$.

A) What is the change in energy of the charge as it moves across the potential difference?
B) If we assume the electric field across the chest is uniform, what is its strength if the paddles are 25.4cm apart?

First step is to take account of what we know.

Given: $q = -145\ \mu C = -1.45 \times 10^{-4}\ C$

$\Delta V = 2.3\ KV = 2.3 \times 10^{3}\ V$

A) What is the change in energy?

This is given by ΔU.

$$\Delta V = \frac{\Delta U}{q}$$

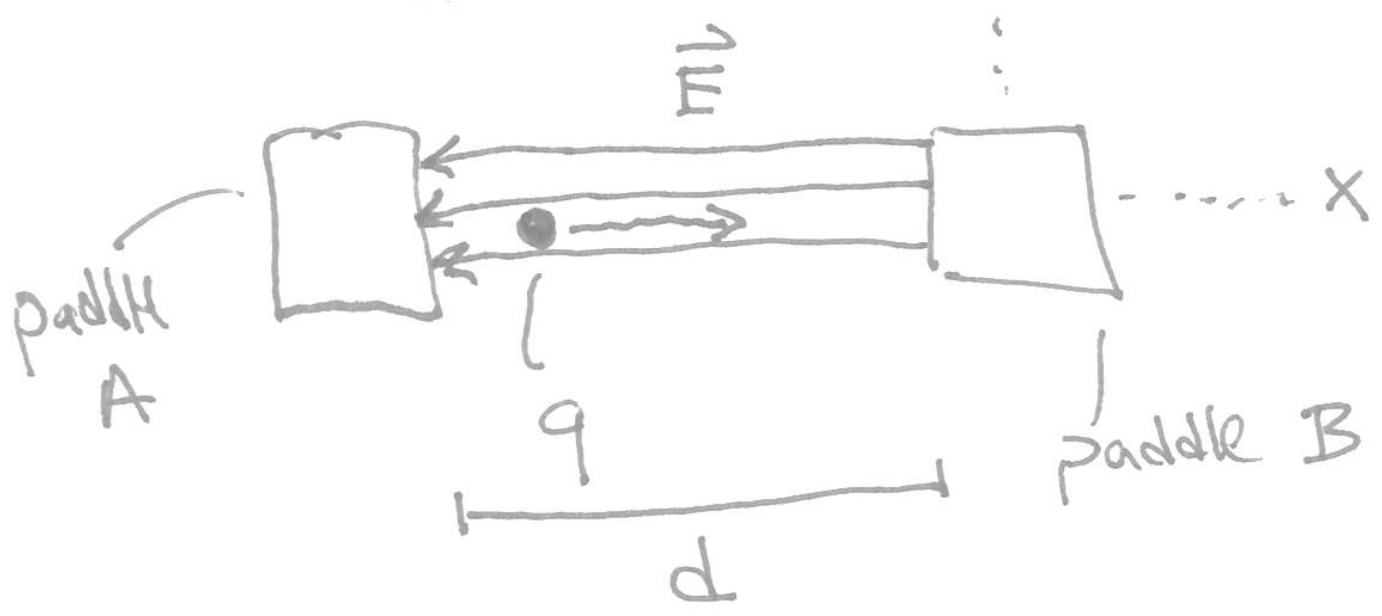
$$\Delta U = q\Delta V = (-1.45 \times 10^{-4}\ C)(2.3 \times 10^{3}\ V)$$

$$\Delta U = U_f - U_i = -0.33\ J$$

Notice: This makes sense. The field in the device wants to move charge from high potential energy to low potential energy. $U_f < U_i$ for this to be true. So, this checks out.

B) What is the |**E**| in the chest if we assume it be be uniform?

Sketch the problem and take account of what we know.



Given:

$$d = 25.4\ cm = .254\ m$$

In this case we need to relate ΔU and E.

We can do this through the <u>work</u> done by the field.

$$-\Delta U = W_{field} = \vec{F} \cdot \vec{d} = q\vec{E} \cdot \vec{d}$$

Recall the dot product:

$$\vec{E} = -|\vec{E}|\hat{i} \qquad \vec{d} = d\hat{i}$$

$$\vec{E} \cdot \vec{d} = -|\vec{E}|d(\hat{i} \cdot \hat{i}) = -|\vec{E}|d$$

Thus,

$$W_{field} = -q|\vec{E}|d = -\Delta U$$

$$|\vec{E}| = \frac{\Delta U}{qd} = \frac{0.33\ J}{(1.45 \times 10^4\ C)(.254\ m)}$$

$$|\vec{E}| = 9.1 \times 10^3\ N/C$$

The End for Today